



# Contact Angle

Interactions with the surfaces of competitive swim suits

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PJAS Science Fair 2014

# Reasons for Experimentation

- ▶ Competitive elite swimmer
- ▶ Interested in which suits repel water the best
- ▶ Practice in suits that cost \$30
- ▶ Race in suits that cost upwards of \$400
- ▶ Any correlation between the expense of the suit and how effective they are at repelling water



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# What makes a suit “fast”?

## Drag Resistance

Compression



Water  
Resistance



Seams vs.  
Seamless



# Background Information– Swim Suits

Practice Suits	Technical Racing Suits
Generally inexpensive	Expensive
\$20–\$100	\$200–\$400
Nylon/Elastine	Nylon/Elastine
Low degree of compression	High degree of compression
Seams	Seamless

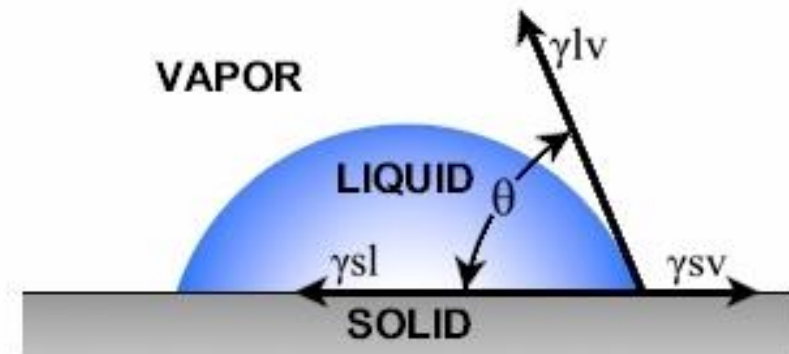


# Background Information– Contact Angle

- ▶ A method of quantitatively determining water resistance
- ▶ Drop of liquid on a solid surface
- ▶ Angle between solid/liquid interface and the liquid vapor interface
- ▶ Angle  $< 90^\circ$ , hydrophilic
- ▶ Angle  $> 90^\circ$ , hydrophobic
- ▶ Angle  $> 150^\circ$ , superhydrophobic

## Young's Equation

$$\gamma^{sv} = \gamma^{sl} + \gamma^{lv} \cos\theta$$



$\theta$  is the contact angle

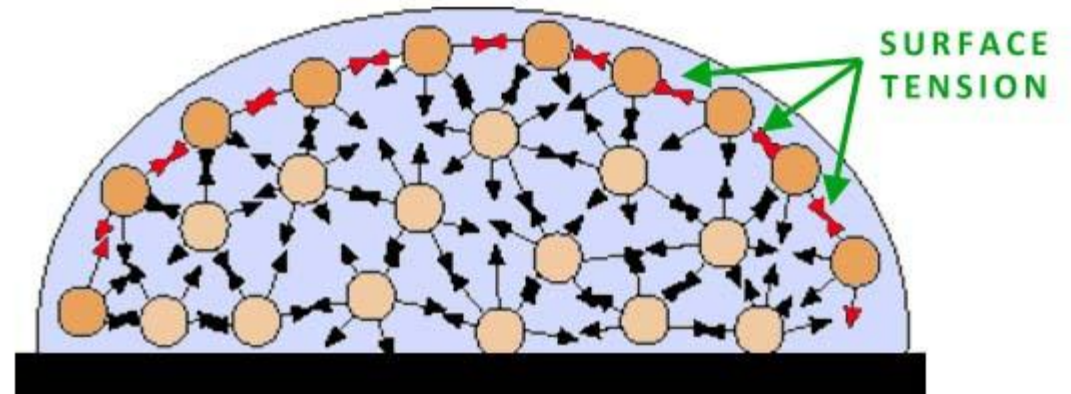
$\gamma^{sl}$  is the solid/liquid interfacial free energy

$\gamma^{sv}$  is the solid surface free energy

$\gamma^{lv}$  is the liquid surface free energy

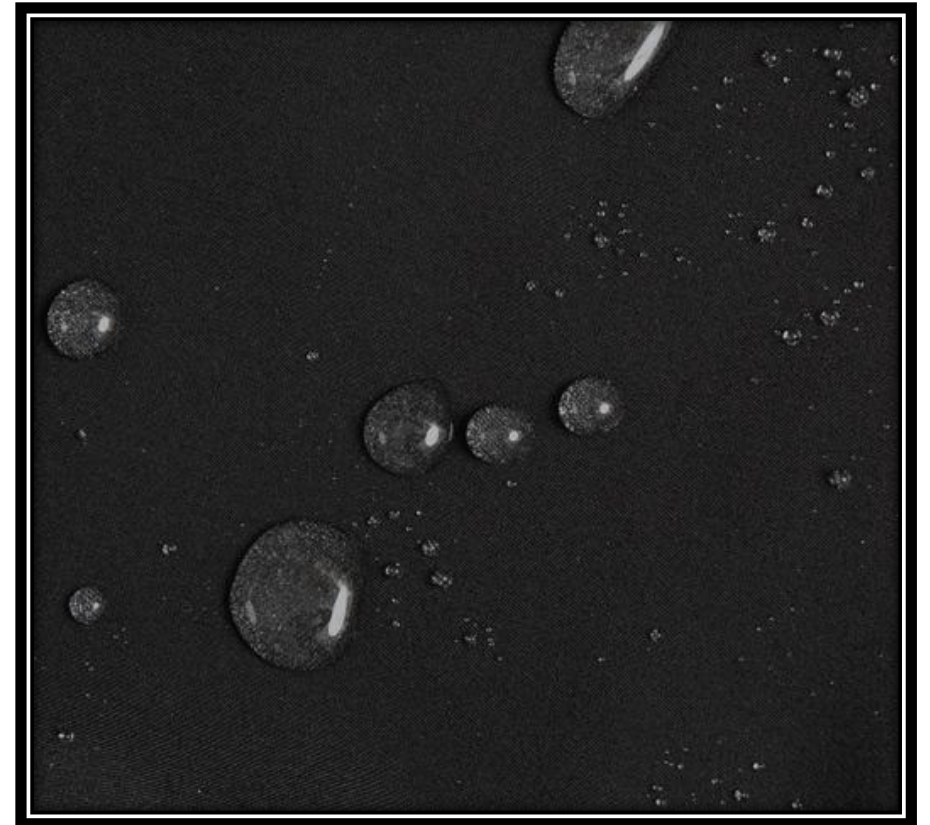
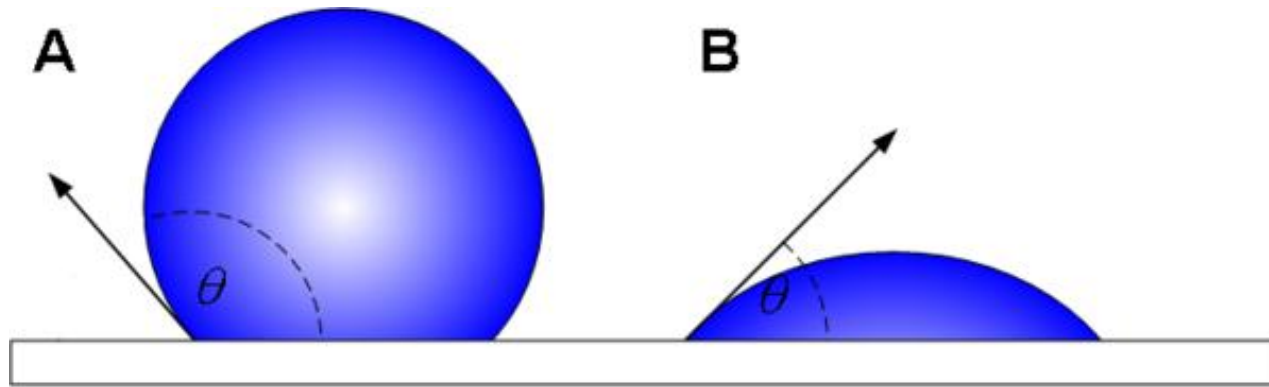
# Background Information– Property of Water

- ▶ Surface Tension
  - Due to the intermolecular forces between water molecules
    - Hydrogen Bonding
- ▶ Molecules below surface = influenced by all directions
- ▶ Molecules at the surface = attracted in one direction
- ▶ Least amount of surface area = sphere



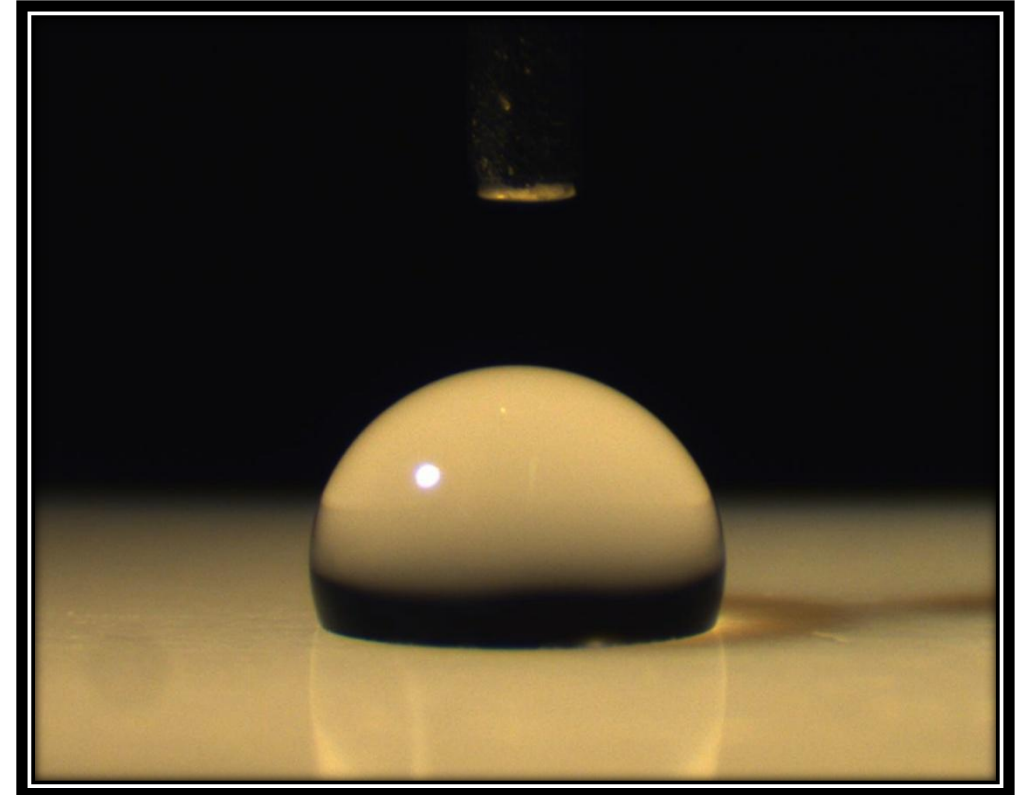
# Question

- ▶ How effective are expensive technical swim suits at repelling water compared to the effectiveness of cheap practice swim suits at repelling water?



# Hypothesis

- ▶ I expect the more expensive a swim suit, the more water resistant it would be. Therefore, the contact angle of expensive suits would be higher than the contact angle of cheaper suits.





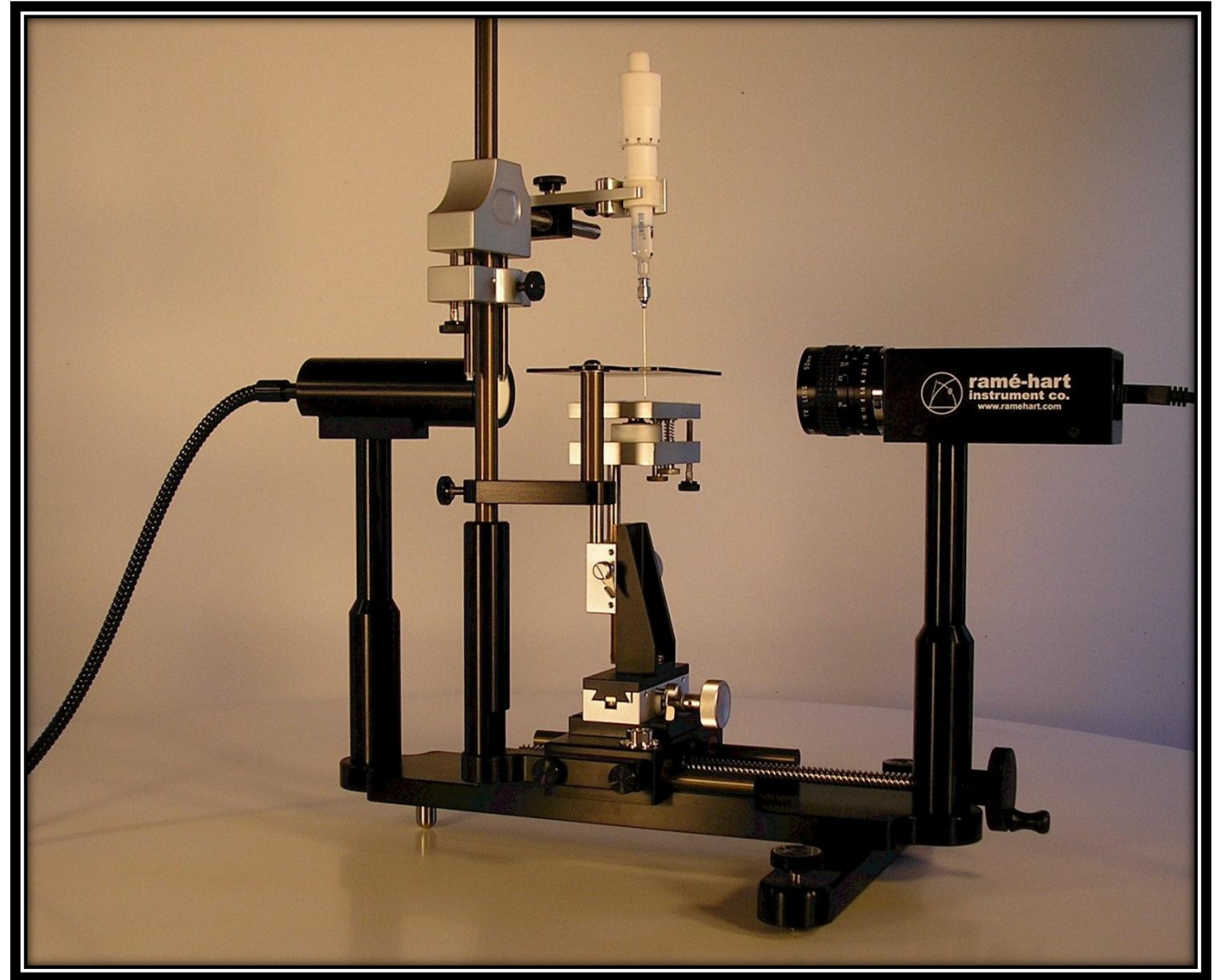
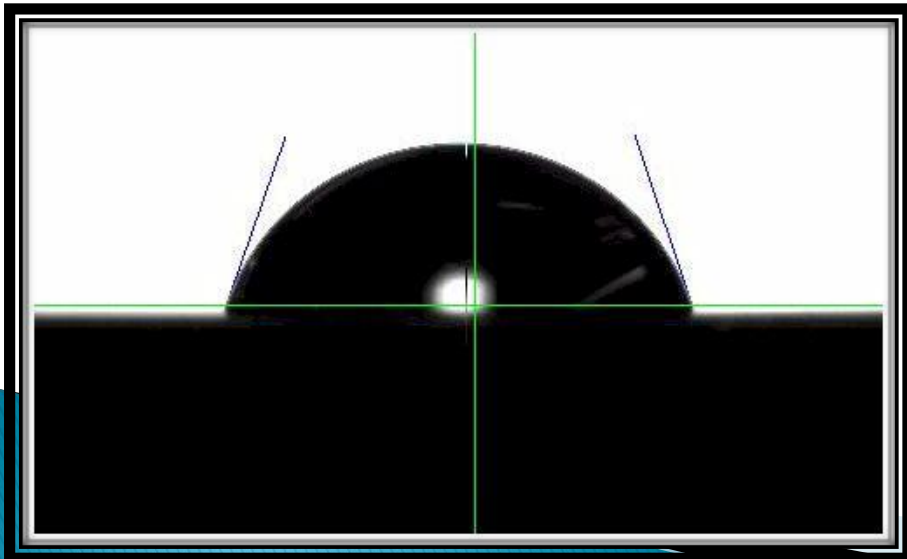
# Equipment

## ▶ Goniometer

- ramé-hart Model 200
  - F4 Series Camera– IEEE1394a FireWire, 400Mbps, 70fps
  - Microsyringe Fixture

## ▶ Software

- DROPimage Standard



# Materials

## ▶ Suits

- TYR Racer
- TYR Tracer–B Series
- Blueseventy Nero TX
- Dolfin Platinum 2
- Speedo LZR Racer Elite
- Speedo LZR Racer Elite 2
- Speedo Fastskin Elite 3
- Speedo Train II
- Speedo Train III
- Speedo Race II
- Speedo LZR Racer Pro
- Speedo Aquablade

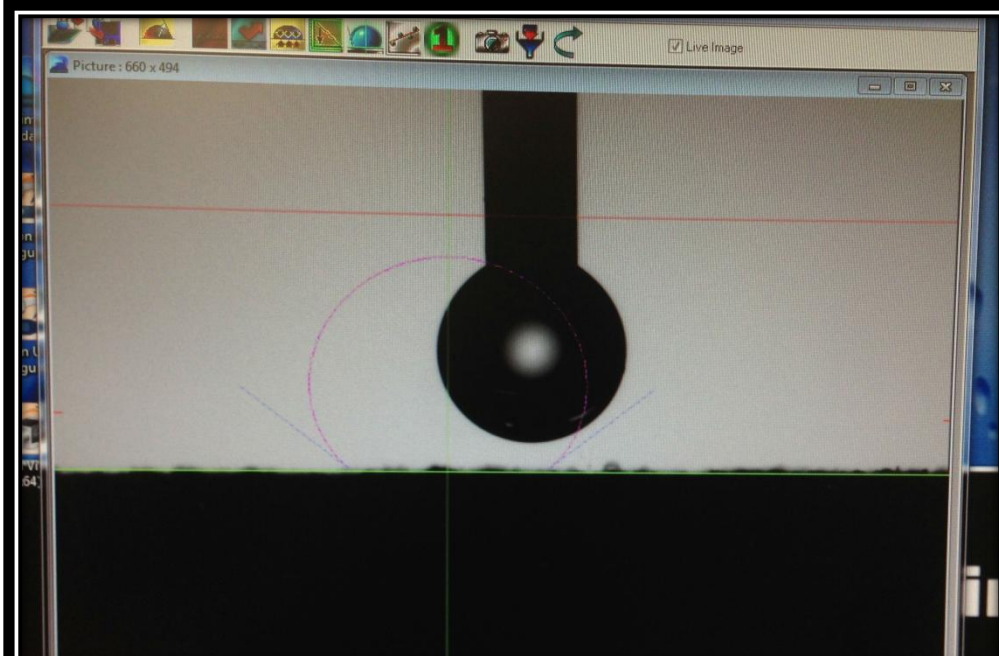
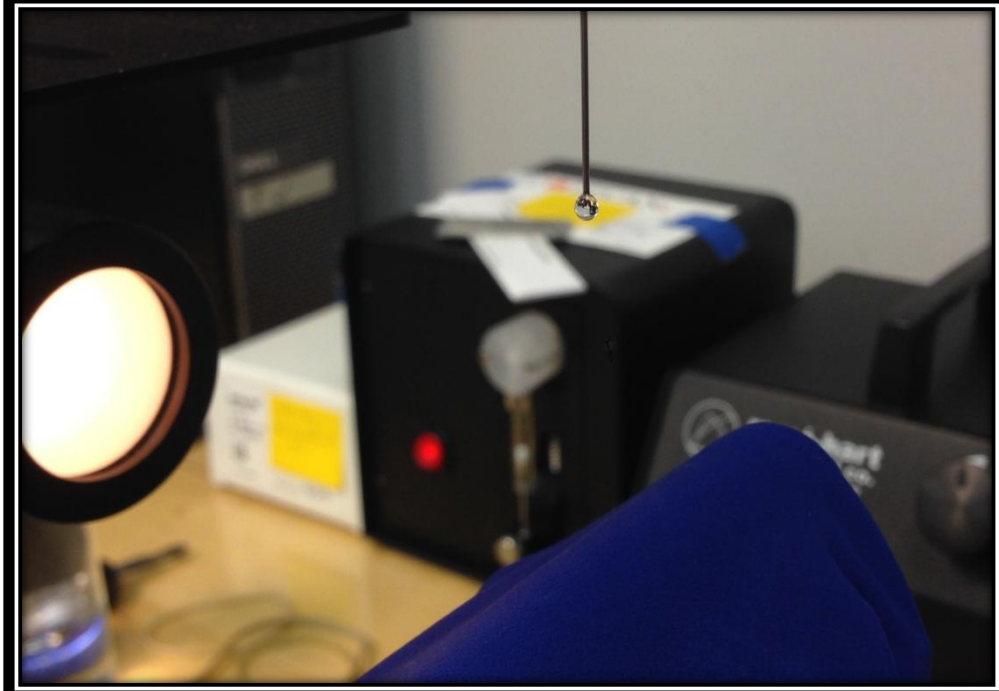
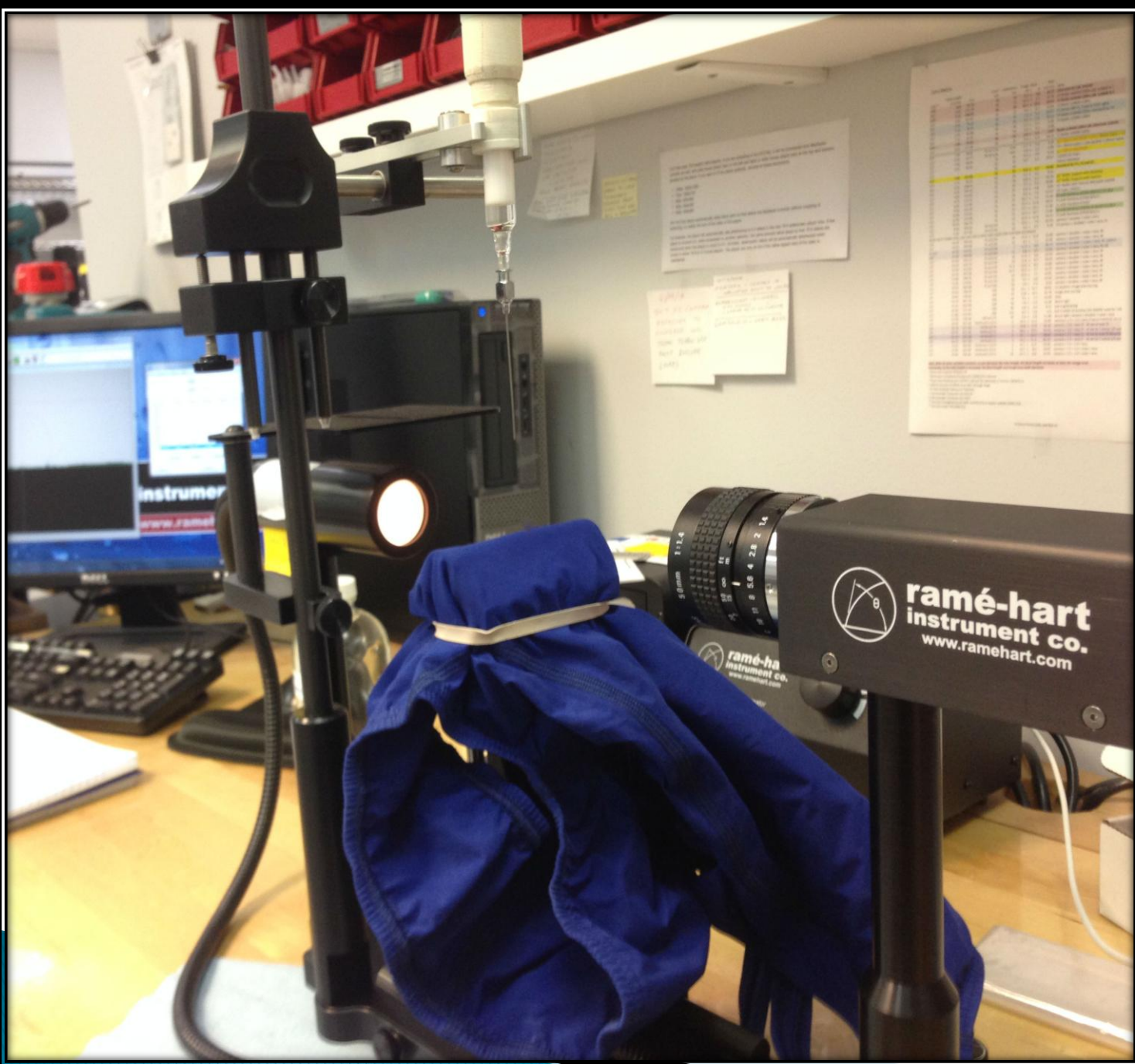
- Speedo FS–Pro
- Finis Vapor Race
- Arena R–Evo+
- Arena Carbon Pro MK2

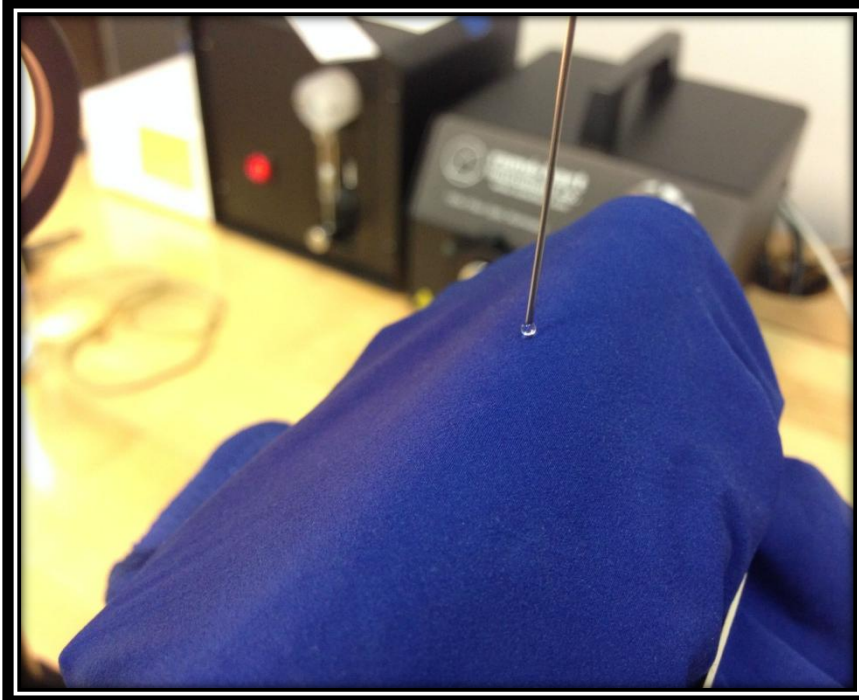
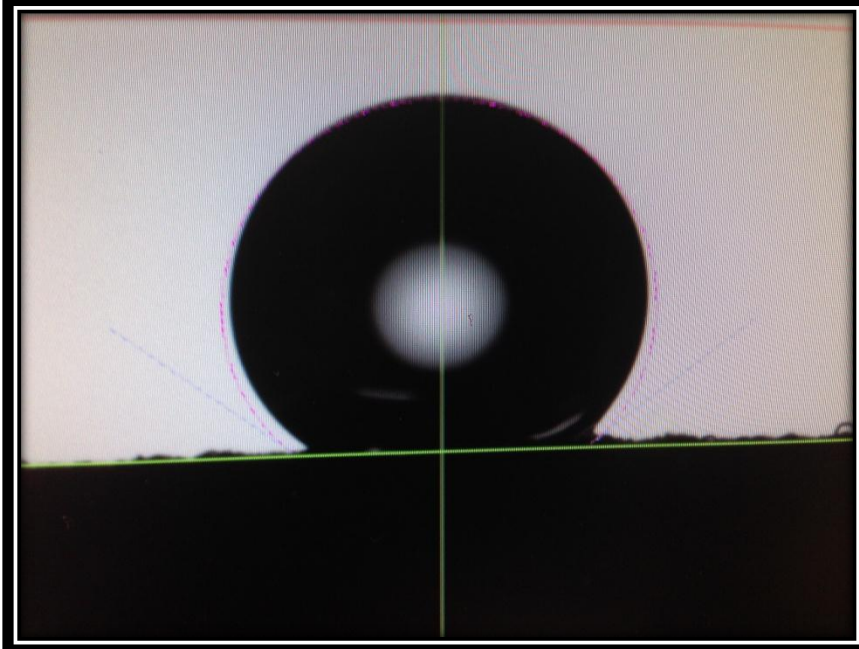
## ▶ Test Liquids

- Deionized Water
- Pool Water Sample

# Procedure

1. Lie the suit flat on the sample stage
2. Using the built in microsyringe, dispense approximately 5  $\mu\text{L}$  of DI water
3. Adjust the camera in order to center and focus the drop
4. Correct green and red lines
5. Change the name of the solid in drop-down box to the correct suit sample
6. Click start and measure
7. Move the sample stage a few turns to the right and repeat steps 2–7 four more times for a total of 5 tests per sample
8. Calculate the average contact angle of the 5 tests per suit





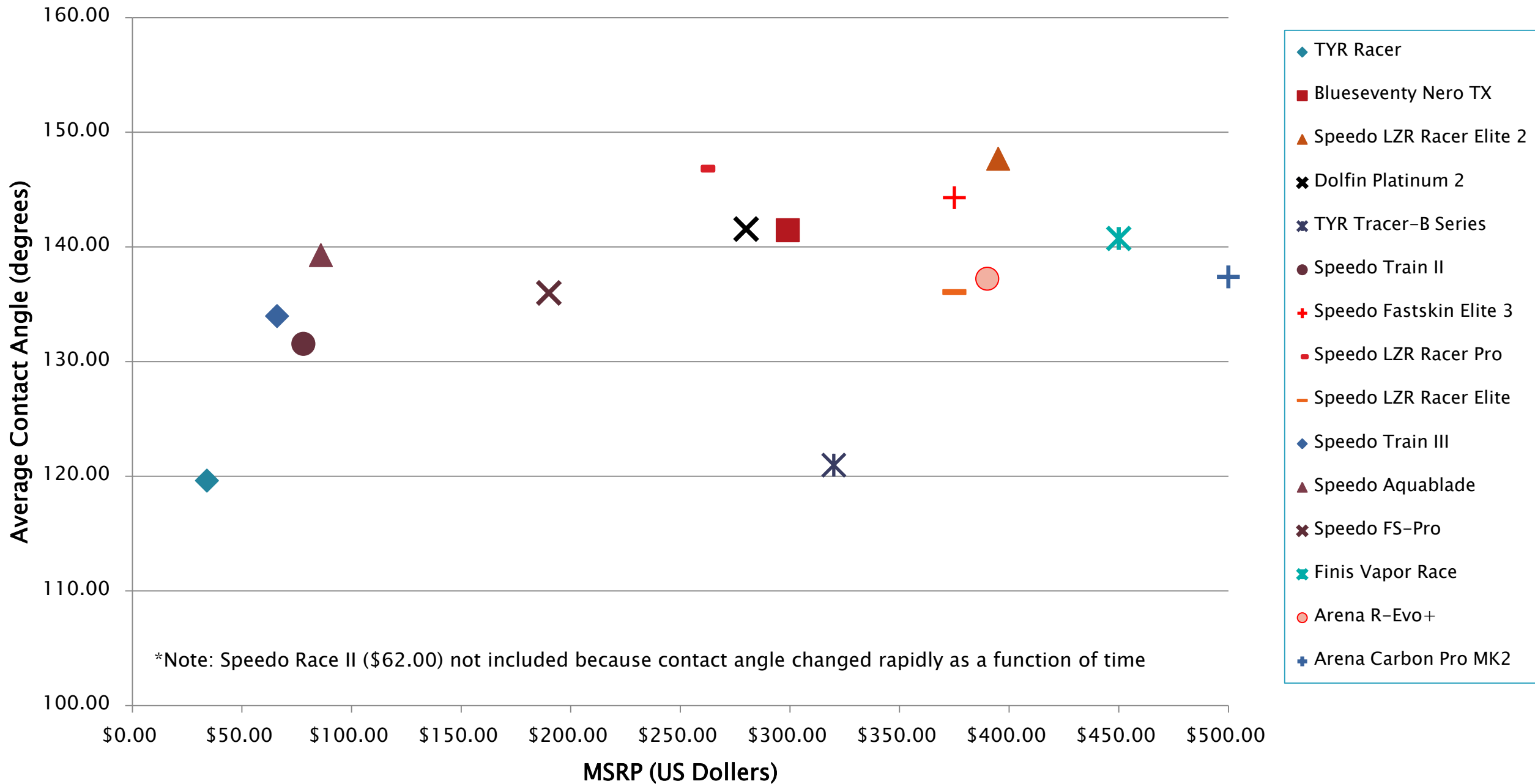
# Lab Results

<b>Solid</b>	<b>Liquid</b>	<b>Left</b>	<b>Right</b>	<b>Mean</b>	<b>Height</b>	<b>Width</b>
NERO TX	Water	135.90	142.90	139.40	1.614	1.375
NERO TX	Water	144.10	143.40	143.80	1.706	1.335
NERO TX	Water	144.00	140.80	142.40	1.831	1.492
NERO TX	Water	137.20	141.50	139.40	1.786	1.531
NERO TX	Water	142.40	139.50	141.00	1.730	1.360

# Average Contact Angle

Suit Sample	Average Contact Angle (in degrees)
TYR Racer	119.62
TYR Tracer-B Series	120.97
Speedo Train II	131.55
Speedo Train III	133.97
Speedo FS-Pro	135.99
Speedo LZR Racer Elite	136.07
Arena R-Evo+	137.23
Arena Carbon Pro MK2	137.39
Speedo Aquablade	139.29
Finis Vapor Race	140.74
Blueseventy Nero TX	141.46
Dolphin Platinum 2	141.56
Speedo Fastskin Elite 3	144.30
Speedo LZR Racer Pro	146.83
Speedo LZR Racer Elite 2	147.70
Speedo Race II	Dynamic Time Dependent

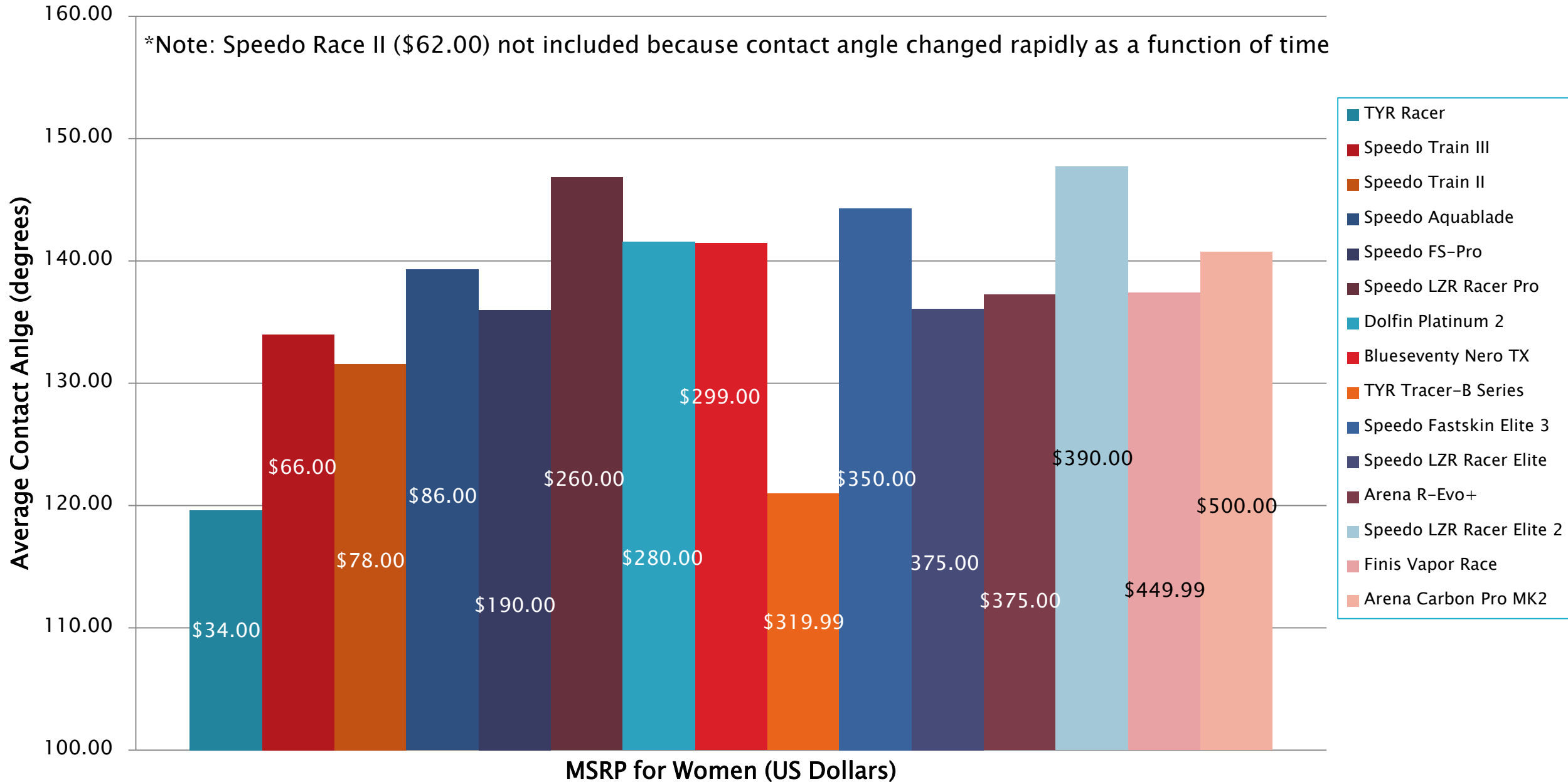
# Average Contact Angle vs. MSRP Price





# Average Contact Angle vs. MSRP Women's Price

\*Note: Speedo Race II (\$62.00) not included because contact angle changed rapidly as a function of time



# Conclusions

- ▶ The suits ranging from \$0–\$260 support the hypothesis that there is a correlation between more expensive suits and a higher contact angle
- ▶ However, suits ranging from \$280–\$500 do not support the hypothesis that there is a correlation between the more expensive suits and a higher contact angle
- ▶ There are exceptions:
  - TYR Tracer B-Series (\$319.99, 120.97°)
  - Speedo LZR Racer Pro (\$260, 146.83°)

# Comparison Test with “Pool Water”

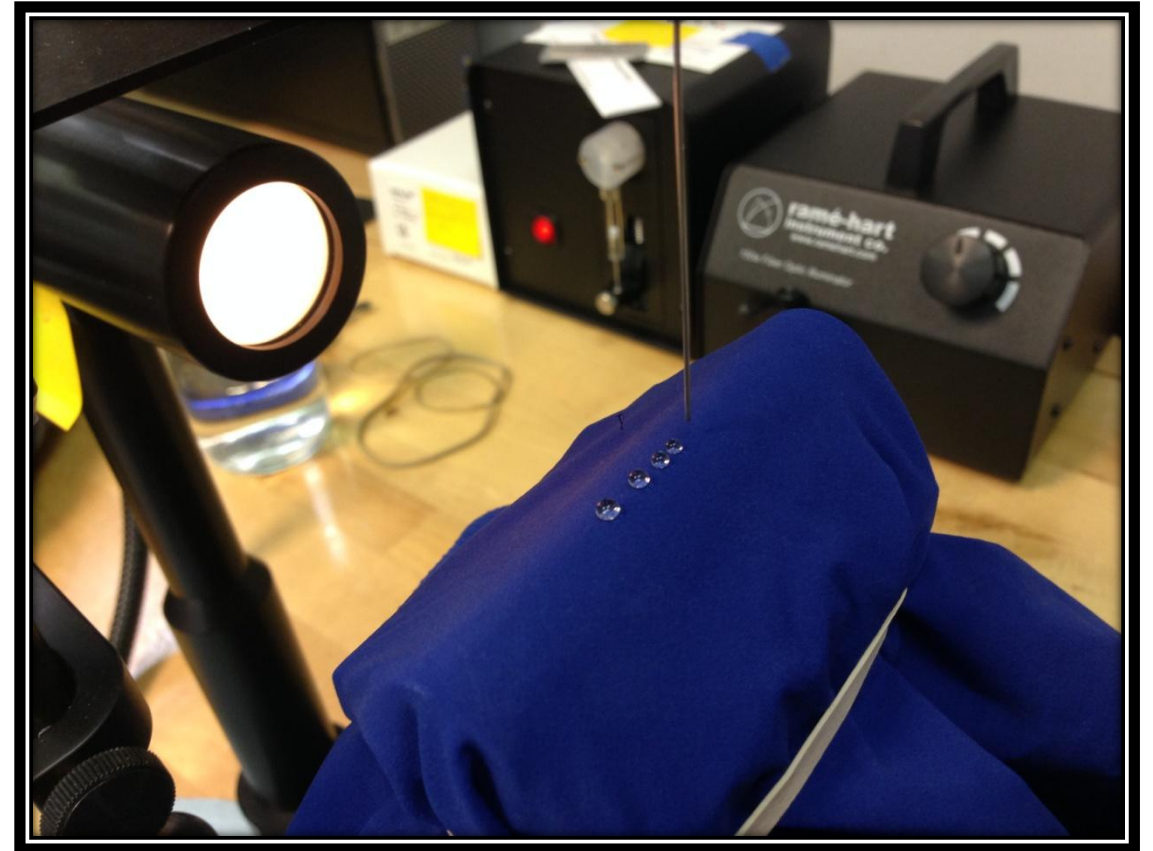
- ▶ Speedo LZR Racer Elite 2
  - Highest contact angle using deionized water
  - Expectation: Pool water has additives
    - Increased density
    - Lower surface tension
    - Therefore; lower contact angle

Deionized Water	CRN Pool Water
147.70°	117.76°



# Sources of Error

- ▶ Only testing a small region of the suit
- ▶ Factors that effect contact angles such as:
  - Evaporation – Reduces contact angle
  - Absorption – Reduces contact angle



# Real World Applications

- ▶ Proving that up to a certain price (\$260), more expensive competitive swim suits will have better water resistance
- ▶ Showing that suits priced above \$280, do not show as much of a difference in water resistance
  - Therefore, assisting swimmers in their purchases of suits  $>$ \$280 to consider other drag resistance factors such as compression and seams.



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